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TECHNOLOGY PLANNING AND PROJECT MANAGEMENT:

IMPROVEMENTS FOR DOST

BY:

VENERANDA ECLAR
PLANNING AND EVALUATION SERVICE
DEPARTMENT OF SCIENCE AND TECHNOLOGY
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FOREWORD

This study was undertaken as my Research Management Project (RMP) under the Lester Pearson Fellowship Pilot Program in Science and Technology Management. The new Pearson Fellowship program was developed to address the need to strengthen the management capacity of government research and science policy establishments. The Fellowship consisted of lectures by key officials of Canadian science and technology institutions, seminars on specific aspects of management of technology and visits to Canadian R&D institutions.

The RMP is an in-depth research project to address a management problem in the Fellow's home institution. It provides a working experience in a number of Canadian institutions relevant to the chosen topic.

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EXECUTIVE SUMMARY

With the increase in the internationalization of the world economy, there comes an increase in global competition. Technical change has helped increase globalization which in turn further accelerates the rate of technical change. In view of this, technology management skills are important. Enterprises and countries must be able to react to technological changes, make more efficient use of limited resources and remain competitive in a changing world. The most important weapon in global competition and the key to national survival may prove to be the skilful management and deployment of technology resources rather than the resources themselves.

Technology planning and project management are part of the technological innovation process. Technology planning involves decisions on what technology areas to concentrate on. Project management is literally information management, research and development (R&D) being a process of creating new information about a product or process. The project life cycle must also be understood together with the critical factors to attend to at different stages.

This study aims to examine approaches including procedures, tools, techniques and principles for technology planning and project management; and to recommend improvements for the Department of Science and Technology.

Five Canadian institutions were studied in terms of the planning concepts and principles implicit in their corporate plan, process and approaches to technology planning and resource allocation, method of project selection, and project monitoring system. These are: Alberta Research Council, Saskatchewan Research Council, National Research Council, and Canada Centre for Mineral and Energy Technology.

The evaluation function was reviewed only in the Energy, Mines and Resources Canada which has conducted it to a relatively larger extent.

It is observed that global competitiveness and how Canadian industries can be made more competitive in the global market is the overriding goal of all R&D efforts. Client or user need is the determining factor in the conduct of R&D work as a basis of relevance. Business-like is the manner of operations that R&D institutions strive for. Specific revenue and leverage targets common in business enterprises are being set. Marketing is a line function in R&D institutions.

Parallel to client orientation and revenue generation is the value given to scientific excellence. The concern for a balanced program mix is reflected in the allocation of resources and activities.

A selective technology approach is evident in that the focus is on a number of strategic technology areas. Collaboration through networks, consortia and partnerships both at the national and international levels is the common mode of operation.

R&D institutions in Canada engage in strategic planning. Technology planning is undertaken primarily through the process of both internal and external consultation. Environmental scanning is undertaken formally or informally. Allocation of resources is primarily based on historical spending and allocation.

Project selection ranges from being purely client-based, that is, dependent on specific client needs; to a committee decision where the major factor is client's funding commitment, it being an indicator of project relevance and the institution's expertise.

Project monitoring is undertaken by the management of R&D institutions. An automated information system consisting of the financial, personnel and technical data on the project is a vital tool in project monitoring.

The evaluation of R&D projects and institutions has been demonstrated to add meaning and significance to an otherwise diffused and unquantifiable undertaking.

The following are recommendations for the improvement of technology planning and project management at DOST:

1. A client/user oriented approach to science and technology (S&T) development by increasing client-based projects and defining the client in strategic R&D.
2. A balanced program mix between exploratory, contract/client based, strategic/non client based and S&T services.
3. Milestones of technology development for more concrete visions .
4. Translation of objectives to performance indicators.
5. A technology-based framework for strategic choices and resource allocation.
6. Strengthening of DOST internal consultation in the updating of the S&T Master Plan.
7. A generic client-centered criteria for project selection with partner/client commitment as the major criteria in proposal prioritization process.
8. An integrated financial-personnel-technical project management information system for R&D to aid project monitoring
9. Institutionalization of the program evaluation function

I INTRODUCTION

1. Need for Management of Technology

The most important weapon in global competition and the key factor to national survival may prove to be the skilful management and deployment of technology resources rather than the resources themselves. In the past two decades, there has been an increase in the internationalization of the world economy. With this internationalization, there comes an increase in global competition. Technical change has helped increase the globalization of the world economy through new developments that have reduced transportation and telecommunication costs. Globalization in turn further accelerates the rate of technical change.

A new dimension in global competition has emerged. With the advent of automated technologies, global competition is no longer based on low production costs stemming from low wages. Quality and innovativeness along with responsiveness to customer needs, efficient distribution networks and after sales service have become increasingly important in capturing markets.

Technology and technical change are major driving forces behind the quality and innovativeness of production, the opportunities for trade, the increase in global competitiveness, and the growth of national income. The development success stories of the past two decades can be attributed in large part to the capacity of those economies to absorb modern technology and to integrate it fully into productive and service activities. Economic development is intimately related to the effective use of resources and to the expansion of the range of goods and services produced to satisfy needs (1).

With technology having become a key factor in national survival, it is not surprising that top managers in the United States, Europe and Japan overwhelmingly rank "leveraging of technology for competitive advantage" the Number One challenge their companies face. Technology is one of the key competitive tools at the command of the winners--and the losers-- in today's marketplace (2). Technology is the use of knowledge, means, processes, and organizations to produce goods and services.

The appearance of significantly new products and processes has been compressed from centuries to decades and finally to years and even months. This reality has brought forth a sense of urgency in dealing with technological problems. The anticipation of change and the response to such a change has become of paramount importance. The response to the impact of technological change on individuals, society, and nature, therefore provides a rational framework for the management of technology.

In order to use technology successfully, a country needs technological capability or technology management skills. This should include the ability to scan, assess, select, use, assimilate, adapt, improve, and develop technology that is appropriate to changing circumstances. Technology management skills are important because technology is constantly changing. Enterprises and countries must be able to react to and take advantage of such changes and explore new possibilities to make more efficient use of limited resources and to remain competitive in a changing world. That is why the management of technology has become an issue of such tremendous importance for global competition and national survival.

2. Scope of Management of Technology

Technological changes are major factors in issues concerning individuals, society, and environment. As such, they require analyses and decision making at international, national, and organizational levels. The traditionally narrow view of management of technology as a discipline being relevant only at the factory level has been expanded to a wider context to include broader issues.

The concept of management of technology has evolved to mean: a) rational use of existing technological assets; b) identification of future technological possibilities and opportunities; c) Research and Development (R&D) management; d) timely adoption and implementation of relevant technological innovations; and e) responding to and coping with the impacts and the effects of technological changes on individuals, organizations, societies, and nature in this shrinking globe (3).

Specifically, management of technology deals with such subjects as science and technology policy, strategic planning, process of technological innovation, technology transfer, methods of R&D management, technological entrepreneurship and new ventures, product and process life cycles, technological change, quality and productivity issues, and education and training in the management of technology.

Managing technology is concerned with managing change. It focuses on integrating technical functions (R&D, engineering, and manufacturing) with business functions (marketing, finance and human resources) (4). Technology is treated as an integral part of strategic planning, along with finance and marketing be it at the company or the national level.

3. Status of Technology Planning and Project Management at DOST

Technology planning and project management are areas of management of technology of major concern to the writer as her functional areas at the Department of Science and Technology (DOST). The rationale for the study is provided by the following description of the Philippine Science and Technology Master Plan and how technology planning and project management are presently carried out at DOST.

3.1 Science and Technology Master Plan

The Science and Technology Master Plan is an indicative plan which aims to provide national direction and ensure coherence in the S&T efforts of both the public and private sectors.

The goal set is for the Philippines to attain the status of a newly industrializing country (NIC) by year 2000 through the aggressive application of science and technology (S&T). Science and technology shall be harnessed to realize the national aspiration of industrialization and better quality of life.

A strategic planning approach is adopted with the establishment of three strategies and identification of leading edge areas as means toward the year 2000 goal. The three strategies are: 1) Modernization of productions sectors through transfer of technology from local and foreign sources; 2) Upgrading of R&D capability; and 3) Development of S&T infrastructure including manpower and scientific culture. The plan also defines the S&T policies and describes specific programs under each strategy.

The focal point of efforts towards industrialization are the so-called 15 leading edges. This is an attempt at selective technology development based on comparative advantage and maximum use of resources. Leading edges are the sectors where products and services have potential socio-economic contribution in terms of increased productivity, increased value-added, and expanded range of locally produced goods and services. These are:
1) Agriculture; 2) Aquaculture and Marine Fisheries; 3) Construction; 4) Electronics, Instrumentation and Control; 5) Emerging Technologies; 6) Energy; 7) Food and Feeds; 8) Forestry and Natural Resources; 9) Information Technology; 10) Metals and Engineering; 11) Mining and Minerals; 12) Pharmaceuticals; 13) Process Industry; 14) Textile Industry; and 15) Transportation.

These leading edges correspond to the major sectors of the economy. Within each sector, specific commodities, products or process where a leading edge can be created are identified. Based on these, programs and projects are developed. There is, however, the commonly expressed need to prioritize the leading edges, the specific areas within each leading edge, and among programs and projects.

The plan reflects a multisectoral approach to S&T development. It describes the government, private sector and academe as the components of the infrastructure for implementation.

The targets set are in terms of the UNESCO norm of one percent of GNP for R&D expenditures and 380 for R&D personnel per million population.

This is the first S&T Master Plan to be formulated and it is meant to be a rolling plan. Updating would be necessary in 1992, two years after its approval, and in time for the start of the new administration and the formulation of the successor plan to the Medium Term Philippine Development Plan.

The updating exercise will benefit from a review of the corporate plans of leading Canadian institutions in the absence of a national S&T plan for Canada. The comparative analysis of planning principles and current directions will provide insights into the improvement of the plan content.

3.2 Technology Planning

National technology planning in the Philippines is spearheaded by the Science and Technology Coordinating Council (STCC) which is a Cabinet level body chaired by the Secretary of DOST . Its members are nine Secretaries of relevant line departments, two representatives from the private sector and one representative from academe.

Created on April 4, 1989 through Executive Order No. 123, the STCC has, as its major mandate, responsibility for the formulation, updating and revision of a Science and Technology Plan. The Secretariat of the STCC is the Planning and Evaluation Service (PES) in cooperation with the staff of the five sectoral coordinating councils of DOST. The preliminary analysis and organization of data for decisions are undertaken by the PES.

Priority areas of S & T development are determined through a participative process of consultation, discussion and consensus among experts and stakeholders of S & T. Socio-economic data are gathered, relevant issues in the environment are considered and state-of-the art of technologies are reviewed. The national priority areas in science and technology development or the leading edges are determined at the STCC level. Specific areas within each leading edge as well as the programs, projects and the approximate costs are determined by a technical panel. The technical panel has members from the private sector, academe and government. See STCC Organizational Chart, Figure 1.

Funding of projects under each of the 15 leading edges is coordinated by the five S&T councils of DOST. See DOST Organizational Chart, Figure 2. One source of funding is the government appropriation for the S&T councils. The Office of the DOST Secretary has a grants-in-aid fund part of which is allocated to the 15 leading edges. In addition, foreign development assistance is being tapped.

Funding from the S&T councils is largely determined by historical appropriations. The percentage distribution of the grants-in-aid fund is arbitrarily decided by the Office of the Undersecretary for R & D. The selection and endorsement of projects for foreign assistance are coordinated by the PES. Instead of being on a first-come, first-served basis, efforts are being made to rationalize this process through a more universal selection based on agreed criteria.

Since attaining a leading edge in the areas identified involve strategic choices toward a common goal, a framework or method to facilitate decision-making is needed. A more systematic approach will help ensure that vital information is obtained and options are laid out such that decisionmakers are more conscious of their choices. Lessons learned from the Canadian approaches will improve the process of decision-making on what areas of technology development will be pursued by the Philippines.

3.3 Project Selection

The selection of projects for each leading edge is undertaken by the sectoral coordinating council under the coordination of the STCC Secretariat. The S&T council and PES staff carry out preliminary evaluation based on separately agreed criteria. Projects are then elevated for review by technical committees.

The mode of selection ranges from a quantitative rating of the project based on the criteria, to a committee consensus, to a management decision. The criteria followed vary, at the staff and committee levels, but by and large, they include the following parameters:

-Consistency with national priorities
-Originality of the proposal (not a duplication of previous or ongoing studies)
-Potential socio-economic benefits
-Magnitude of impact
-Technical feasibility
-Institutional capability of implementing institutes
-Availability of funds required for implementation

There is a need to adopt a standard set of criteria across DOST sectoral councils for selecting projects under the leading edges. The objective is consistency in selection and a more synchronized effort in implementing projects in the leading edges. Thus, the search for an improved project selection criteria and mode of selection.

3.4 Project Monitoring

Monitoring of DOST projects is undertaken by the Planning and Evaluation Service (PES) of the Office of the Secretary. At the start of a new project, a workplan is submitted with the quarterly and annual milestones and their percentage completion if completed. A similar financial workplan is also prepared. These may be revised based on actual accomplishments. An updated annual workplan is submitted for the incoming year.

Quarterly reviews are conducted by the Undersecretary in-charge of the institute with the Secretary in attendance, the Assistant Secretary for Policy and Planning assisted by the PES. Highlights of the review are then summarized by the PES and circulated to heads of agencies for information and appropriate action.

This system has been in place only for one year and an automated R&D information system is being pilot tested. There is a need for a system that simplifies reporting of technical accomplishments to reduce paperwork while providing useful data needed for the review process. Reporting of the financial side of projects is in practice neglected: thus, the need to examine the project tracking system in Canadian R&D institutions.

3.5 Program Evaluation

The program evaluation as a function which examines on a periodic basis the rationale for the project or program is not formally undertaken by DOST at present. No program, in recent years, has been subjected to a systematic gathering of verifiable information on its results and cost-effectiveness. Evaluation has only been done at an institution level such as that of PCARRD.

The Science and Technology Master Plan outlines various programs intended to produce certain benefits. These should be evaluated to establish impact not only of the programs themselves but of the whole plan.

The DOST has a Planning and Evaluation Service, created in 1986, to render staff assistance to the DOST Secretary in the areas of policy, planning, monitoring, coordination, resource assessment and evaluation. To some extent, evaluation is undertaken with the national S&T indicators to determine the status of Philippine S&T. Initially, the indicators used pertain to R&D expenditures, R&D personnel and patents.

Evaluation should now be initiated to complete the management cycle of planning, selection, monitoring and evaluation. A review of how the evaluation function is carried out in Canada including concepts, methodologies and cases will serve as an initial learning experience towards institutionalizing program evaluation at DOST.

II PURPOSE AND SCOPE OF THE STUDY

The study aims to:

1. Examine approaches, procedures, tools, techniques and principles for technology planning and project management in selected institutes in Canada; and
2. Formulate recommendations for the improvement of technology planning and project management at DOST.

The study should cover the following:

1. Analysis of the corporate plan specifically on policy directions and planning principles reflected therein;

2. Technology planning including how priority areas are determined and resources allocated, and by whom;

3. Selection of projects by whom, how and what criteria are used;

4. Project monitoring primarily information systems as a tool of this function; and

5. Project/program evaluation as an institutionalized function in a government organization.

III THEORETICAL FRAMEWORK

1. Technological Innovation Process

The process of technological innovation is composed of the generation of an idea or invention; and the conversion of that invention into a business or other useful application (5). Innovation is, therefore, invention plus exploitation. Whereas invention is marked by discovery or state of new existence usually at the lab or bench, innovation is marked by first use, in manufacturing or in a market.

Technologically innovative outcomes come in many forms: incremental or radical in degree; modifications of existing entities or entirely new entities; embodied in products, processes or services; oriented toward consumer, industrial or governmental use; based on various single or multiple technologies.

The technological innovation process is a highly iterative process which encompasses technology planning and R&D project management. It consists of six stages, namely: 1) recognition of opportunity; 2) ideas formulation; 3) problem solving; 4) prototype solution; 5) commercial development; and 6) technology utilization and/or diffusion. See Figure 3.

The task undertaken during Stage 1 is coming up with one or more technical and/or market goals that stimulate initiation of a research, development and/or engineering (RD&E) project. Technology planning is a major activity at this stage. The relevant managerial question for this stage is how can more and better goals get generated? Which people, which structures, which strategies can be employed?

R&D project management encompasses Stages 2, 3 and 4. It involves the fusion of a recognized technical feasibility and potential demand into a design concept at the idea formulation phase of Stage 2. This is followed by the search and use of technical information through secondary sources, experiment and calculation at the problem solving stage or Stage 3. Stage 4 is the development of solution through adoption or adaptation of existing technology or an invention in prototype. The managerial issues at these stages are project planning, scheduling monitoring and control, technical work supervision, business and financial coordination relating to the R&D project.

In commercial development at Stage 5, the task involves in-depth specification and manufacturing engineering of ideas that have by now already been reduced to an acceptable working prototype. The managerial issues in this stage involve coordinating a number of engineers of different disciplinary backgrounds toward achieving, within previously estimated development budget and schedule, a predefined technical output ready for manufacture in large volume, reliably, and at competitive production costs.

2. Technology Planning

Technology planning as an initial activity of the innovation process consists of identifying which technologies on which to concentrate. It can include the identification of which technologies to work on; which technologies it should not work on; which technologies should be sourced outside; and the reasons underlying these decisions (6).

Technology objectives should be supportive of the business or national strategy. Integrating technology and business or national strategy is vitally important since both functions must have common goals and must operate inside a defined framework. R&D must play an integral role in shaping business or national strategy and tactics. Likewise, the business units must set goals and participate in shaping strategy for R&D.

The realignment of technology with business strategy can be undertaken by first defining the business objectives and the business strategy. From the business strategy, the technology objectives are derived which lead to the definition of the technology strategy. The final step is the identification of specific actions which are required to carry out the technology strategy in practice.

3. R&D Project Management

The dramatic success of such revolutionary products as the transistor and oral contraceptives brought about the realization that new streams of revenue and benefits can be created if R&D were more predictable and more responsive to the needs expressed in the marketplace. Even if "you can't plan invention", R&D managers realized that program goals could be set and met successfully. This, plus intense competition, greater demand for more products and specific needs of stakeholders including government regulators prompted managers to direct their energies not only to science but also to such concerns as formal planning, tracking and evaluation of projects.

R&D can be viewed as a process of creating new information about an event, process or product. Project management is a specialized part of the R&D process that serves the purpose of creating and managing information. Project management was developed to permit this new information to be generated under more organized and controlled circumstances. The control does not, however, decrease the number of technical changes that occur --rather, it increases the awareness of these changes.

Project management is also the major mechanism for integrating information that is generated in R&D and transferring it to other parts of the organization or relevant phases in the innovation process such as the marketing and manufacturing. Thus, the role of managing the generation (collection), organization and dissemination of information becomes critical to the success of R&D.

In summary, R&D is a process for creating new information, and project management is literally information management (7).

When projects are initiated, a plan is developed to reach the goal set by top management. Since the time horizon is quite long, checkpoints or milestones become essential in managing the project. With these, movement through the development cycle can be measured and observed.

Successful projects never seem to follow a straight line to the goal in the initial plan. People used to believe this was due to the inherent unpredictability of R&D and the process of creating new information. Information must be generated about the potential product and must be tried in new and different ways as part of the development process. Time delays are not desirable but, deviations should be expected. They are generally useful in terms of the information they generate.

Deviations from the original plan are considered acceptable as long as they fall within certain limits. When deviations go beyond a certain level, management must get involved since the delivery time will be significantly affected and will have implications for resources.

Successful project management systems develop mechanisms which support the management of information (8). Some examples are the following:

i) Agree (in writing if possible) to the goals of the project. This should include intense discussion by the people concerned about the amount and type of work required, the priority assigned to the project and the needed resources.

ii) Regular meetings are a must. One purpose is to solve problems and plan tactical changes. The other is to review project progress/status and to exchange information across disciplines.

iii) Status, plans, and issues should be reported regularly to all concerned units in the organization in order to keep activities visible and avoid surprises.

iv) A project list/data base which is made available to all is essential. This is especially useful in matching resources with projects.

v) Good planning and timely completion of work as well as the quality of the results of the work must be part of the reward system. If the scope of the rewards is not expanded to include planning and timeliness, the success of the project management system can become dependent of the good will of the line people to work together, and it may be more difficult to hold them organizationally accountable.

4. **Project Life Cycle**

Effective project management requires an understanding not only of the innovation process and R&D project management, but also of the project life cycle. This is because the project manager is constantly bombarded with a variety of information to consider and issues to resolve. There are critical factors to attend to whose relative importance change depending upon the stage in which the project currently resides. Likewise, each project life cycle stage requires certain tools and approaches to efficiently manage the project.

While many different examples of project life cycle exist, with a variety of numbers of distinct stages, it basically consists of four stages, namely: Conceptual, Planning, Execution, and Termination (9).

Stage I--The conceptual stage involves the initial determination of a need for a project. Preliminary goals and alternatives are specified as well as the possible means of accomplishing the goals.

Stage II--Once goals have been agreed upon,a more formal set of plans are developed in order to accomplish these goals. These planning activities often involve the definition and allocation of specific tasks and resources.

Stage III--The actual "work" of the project is performed during the execution stage. Materials or resources are procured, the system or project is produced, and performance capabilities are verified.

Stage IV--Once the project is completed, several final activities must be performed, including the release of resources and transfer of the project to the clients, as well as the reassignment of project personnel. There is often some form of project review and evaluation to assess relative successes and failures, their likely causes, and possible corrective actions in case they occur again.

A recent study revealed ten factors which are critical at various stages to the successful implementation of R&D projects. These factors are:

i) Project Mission: Initial clarity of goals and general directions.
ii) Top Management Support: Willingness of top management to provide the necessary resources and authority/power for project success.
iii) Client Consultation: Communication, consultation, and active listening to all impacted parties.
iv) Project Schedule/Plans: A detailed specification of the individual action steps required for project implementation.
v) Monitoring and Feedback: Timely provision of comprehensive control information at each stage in the implementation process.
vi) Communication: The provision of an appropriate network and necessary data to all key actors in the project implementation.

vii) Technical Tasks: Availability of the required technology and expertise to accomplish the specific technical action steps.
viii) Personnel: Recruitment, selection, and training of the necessary personnel for the project team.
ix) Client Acceptance: The act of "selling" the final project to its ultimate intended users.
x) Trouble-Shooting: Ability to handle unexpected crises and deviations from plan.

Figure 4 shows what success factors are critical at each project stage.

IV CANADIAN APPROACHES TO TECHNOLOGY PLANNING AND PROJECT MANAGEMENT

Five Canadian institutions were closely examined in terms of the planning concepts and principles implicit in their corporate plan, process and approaches to technology planning and resource allocation, method of project selection and project monitoring system. The evaluation function was reviewed only in one institution which has conducted it to a relatively larger extent. The institutions reviewed and their management of technology (MOT) approaches are summarized in Table 1.

1. Alberta Research Council

1.1 Corporate Plan

The Alberta Research Council's (ARC) goals and strategies for the 1990's are set out in its corporate plan, "A Vision for the Year 2000". The plan maps out the progress of ARC toward its vision of being an internationally recognized technology corporation and a valued and important partner in the emergence of a globally competitive Alberta.

The plan adopts a dual approach to technology development by setting a goal on the supply side, that is, to enable ARC to be an internationally recognized technology corporation. On the demand side, it sets the goal of helping Alberta industries meet global competition.

The Plan reflects an integration of the R&D strategy of ARC with the economic strategy of the province of Alberta. ARC plans to carry out R&D in a businesslike manner and in close tandem with the economic activities of the province, with scientists keenly conscious of the needs of the market economy.

Consistency with economic requirements and external collaboration are manifested in ARC's corporate goals which will be the measure by which future programs and activities will be selected. The goals are to link advanced technology to the resource sector; to ensure sustainable resource development of the wealth-generating sectors of the economy; and to establish co-funding and partnership arrangements with the private and public sectors.

The plan also sets a specific revenue target of 50 percent from nonprovincial government sources at the end of the decade from the present 30 percent. The other 50 percent will be provided by the provincial government. This clarifies its position as a provincial research organization which still pursues a social objective, unlike other similar organizations, while recognizing the need to generate revenue from its activities.

External collaboration is further emphasized in its corporate strategies consisting primarily of linkages with the private sector, the Alberta government, Canadian research institutes, Alberta universities and colleges, collegial relationships with scientists and engineers in many countries and participation in multidisciplinary multimillion dollar projects. Establishing foreign linkages is also consistent with ARC's vision not only to be internationally renowned but to impact on global competition.

The plan places greater emphasis on the marketing of ARC's expertise and programs to all stakeholders. A new marketing arm will be established to promote transfer and use of developed technology.

The implementation of the corporate plan is also outlined. The organizational set-up is described, along with planning procedures to identify the right programs, technology transfer mechanisms and critical success factors for the attainment of the vision.

Each department of ARC also prepares a detailed business plan which essentially consists of a situation analysis of the economic sectors which they serve, their missions and programs.

The vision is made concrete by the milestones established in the departmental plans. These are firm statements on the kind of technology outputs at the end of the plan period. For the Coal and Hydrocarbon Processing Department, for example, the movement will be from high conversion upgrading, coal-oil agglomeration, waste processing and hydrogen production in 1990, to advanced processing technologies, applied surface sciences, high performance separations and hydrogen systems in 2000.

1.2 Technology Planning

Consultation was the main mechanism through which A Vision to the Year 2000 and the Department Plans were developed. Significant inputs were solicited from ARC's key stakeholders, clients and staff.

ARC has sharply focused its nine research business units on key sectors of Alberta's economy. These are: coal and hydrocarbon processing, oil sands and hydrocarbon recovery, forestry, manufacturing technologies, biotechnology, electronics, environment, advanced computing and engineering and geological survey.

To be able to identify and respond to emerging trends, the ARC has introduced three planning procedures that involve its staff, departments, corporate management, Board of Directors and clients. These are:

i) Department Planning - where each department allocates 10 percent of its core grant to new projects to adapt to new opportunities. This reflects a value given to long-term research to serve as a base for the requirements of competitive research.

ii) Interdepartment Reallocations - where senior management carries out program changes and reallocates existing funds to new areas where ARC has appropriate expertise and/or facilities. This is carried out annually by involving several departments.

iii) New Building Block - where the Board of Directors identifies opportunities for moving into research areas needed in the province and not currently part of the portfolio of programs. These new building blocks may require the investment of millions of dollars, and therefore need the strong support of government and industry stakeholders.

Decision-making by the Management Committee on what program areas to focus on at the corporate level is aided by a grid model with the two major determinants which are: 1) potential to advance the economy and / or social benefits to Alberta and; 2) commitment of the partner. Relevant quantitative and qualitative data are used as measures of the potential benefit to Alberta. Commitment of the partner refers to the share of clients or co-funders. The various programs being considered are placed on the grid. The various program areas are then ranked according to priority based on discussion and consensus. The ranking also serve as the basis of allocating resources. See example of benefit-partnership grid, Figure 5.

At the department level of ARC, planning decisions are guided by a program committee representing the principal stakeholders.

1.3 Project Selection

The selection of projects within a program at ARC is described as flexible and decentralized. Each department manager is held responsible for projects to be undertaken. An internal pre-selection may be carried out by a committee, the results of which are submitted for review to a technical committee.

The general criteria used are similar to that in technical planning, that is, potential economic and social benefit and commitment of partner. More detailed projections of the market impact is needed as a basis for the selection of new projects. In addition, the technical feasibility and merits of the project are given weight.

1.4 Project Monitoring

Project monitoring at ARC is the responsibility of the manager who is held accountable for the delivery of results. The procedure in dependent on the mutual agreement reached between ARC and its partner as to the frequency of reporting and expected outputs at various points of the project life.

2. Saskatchewan Research Council

2.1 Corporate Plan

The Saskatchewan Research Council (SRC) did not make available a corporate plan. However, various documents indicate that SRC directs its efforts towards the economic objective of developing Saskatchewan business through the processing of new and existing products, and the promotion and marketing of those products nationally and internationally. It plans to work closely with its manufacturing customers to stimulate and support the development and diversification of the economy.

SRC aims to increase contract revenue with the business sector as revenues from government contracts decline. It's present budget of $16 million consists of 30 percent core funding from the provincial government, 40 percent contract revenue from industry, and another 30 percent contract revenue from other government sources.

It is adopting a client service mentality and developing a corporate culture which is professional, businesslike and market driven.

Networks and partnerships are being expanded. A team approach is used by working with government departments, universities and schools, and the private sector. Provincially, SRC works with the economic development infrastructure to assist small businesses. It collaborates with schools and universities in areas of industry related training and research. In line with the marketing of Saskatchewan products and expertise internationally, SRC has several contracts with Pacific Rim countries.

2.2 Technology Planning

Areas of technology development undertaken are those consistent with the corporate theme of SRC which is to apply science and technology for Saskatchewan's development. These are areas which address the diagnosed needs of clients. New opportunities and challenges in its environment are also taken into account. In view of such developments as large government deficits, the increasing production costs of crude oil in Saskatchewan and GATT negotiation setbacks, new directions were taken.

While making efforts to increase revenues, SRC seeks to maintain its national and international recognition as having a leading-edge role in several areas of research. These are in such areas as heavy oil recovery and enhancement, Bovine blood typing, groundwater research, air sampling equipment and farm equipment design. It also wishes to continue to play a significant role in rendering a multiplicity of services to the resource development industries --- agriculture, oil, uranium, potash, gold and diamonds.

Activities which support the corporate business development of SRC are undertaken. These activities include exploring new technological opportunities; coordination of business development initiatives with other organizations; and providing hands-on business development assistance.

2.3 Project Selection

Project selection at SRC is client-based. Most of the projects are uniquely tailored to the needs of the client. Projects are defined through discussion between a client and the scientists or engineers who will carry out the project. Often scientists and engineers visit the client at his/her premises to understand the needs and situation as best as possible. This is followed by an assessment of existing state-of the-art technology through database searches, consultation with the network and other methods. It is believed that the best results are obtained when leading edge technology is applied to serve the real needs and wants of clients.

Some amount of internal research is undertaken to explore new opportunities and to maintain the leading-edge role in certain areas.

In view of the revenue objective, project cost and client funding commitment are important criteria in the selection of projects at SRC. A more accurate computation of the price of R&D services is provided by the SRC pricing model which is shown below:

$$\text{TOTAL} = 2.5 \times \text{hourly salary} + \text{cost of materials} + \text{testing fees} + \text{other expenses}$$

The 250% is comprised the following pre-computed percentages:

- 100% hourly salary to employee
- 27% benefits overhead
- 39% administration overhead
- 84% divisional operating overhead
  - o buffer for nonchargeable time
  - o salary costs for Vice-President and Division Directors operations
  - o internal research
  - o proposals
  - o travel/training
  - o contributions to projects that fit with the long range objectives of SRC
  - o equipment acquisition

2.4 Project Monitoring

Monitoring of accomplishments under large projects is undertaken through regular staff meetings. Since most projects are client-based, the procedure is flexible depending on prior agreement.

However, the financial aspects of projects are monitored using an automated financial information system which integrates the accounting, purchasing and personnel data. It is project-based, unlike the traditional fund-based system of accounting. It basically shows the budget for each item of expenditure, the expenditures to date, and the budget balance. Updates are made on each project upon receipt of the following documents related to project work:

- Project time sheet where each employee makes a daily accounting of the number of hours he/she spends on the projects
- Statement of travel
  - Requisition (Purchase order)
  - Petty cash (items less $50)
  - Work order
  - Invoice (Bill client)

Financial reports come in three forms, namely:

- Project ledger for Project leader
- Project summary for Middle/Senior management
- Quarterly statement for senior management and Board of Directors

3. National Research Council

3.1 Corporate Plan

NRC's long range plan for 1990-1995 is entitled "The Competitive Edge." It seeks to align NRC efforts with the socio-economic objective of improving Canada's competitiveness and well-being of Canadians. It operationalizes NRC's continued commitment to support innovation in Canada through scientific and engineering R&D.

The primary objective being pursued is to develop the means by which the total level of R&D that NRC stimulates and encourages others to perform can be doubled by the year 2000. The intended outcome of the current plan is that NRC be positioned by 1995 to achieve this end-of -decade objective. Towards this objective, three strategies have been established, namely: maintain world-class research, promote partnerships and collaboration to ensure relevance, and develop Canada's competitiveness.

The long range plan adopts three themes which are important to positioning NRC for the twenty-first century. These are world-class research, research that is relevant and national competitiveness. Values that have characterized NRC's strong role in Canadian science and engineering research are incorporated. These are: dedication to the public interest, quality service to its clients, respect for its employees, excellence in technical skills, and efficiency and accountability in the management of its resources.

The plan emphasizes building new partnerships with industry, consortia, universities and other S&T performers to optimize the application of limited resources. In addition, it recognizes the need for strategic alliances and international partnerships to source certain technologies necessary for the country to prosper.

The plan reflects a selective approach in S&T investments. It aims to develop Canada's competitive abilities in the key sectors likely to govern future global trade. NRC has identified several long-term scientific and technical areas of priority which are: biotechnology, industrial materials, transportation technologies, technologies for construction industries, environmental chemistry, molecular sciences, advanced manufacturing, and information technologies.

Another principle advocated in the plan is responsiveness to client needs. Client service is considered a critical element of NRC's mission.

Accountability is promoted in that the plan sets performance indicators for its primary and strategic objectives. These revolve around the client orientation whereby NRC seeks recognition by scientists and industrial clients as the primary Canadian research centre.

3.2 Technology Planning

In preparing the long range plan, NRC reassessed its mandate, objectives, and priorities. It initiated a broad consultation strategy involving key stakeholders, clients and colleagues in Canada's R&D community. Long-standing assumptions concerning NRC's nature and directions were re-examined through external consultations and internal reviews. The managers, staff and NRC Council with members outside government, played an active role in determining its guiding principles, developing its strategic directions, and defining its corporate objectives.

The consultations were supplemented by round-table discussions and reports concerning NRC's strategic and operational roles. The Science Council of Canada and the Conference Board of Canada led these activities which involved representatives from outside government, including business, universities, provincial research and media organizations. These forums produced specific advice and explored a wide range of perspectives regarding how NRC should prepare itself for the future.

A strategic planning approach was adopted in the formulation of the NRC long range plan. The exercise encompassed the review of fundamental organizational goals and the deployment of resources required. As described above, it involved actions to develop and document the future role of the organization, its corporate goals, values, policies and objectives. From these, the programs, projects and tasks that constitute the ongoing work of the organization will be drawn.

Environmental scanning was undertaken as part of strategic planning. The long range plan has been developed to take into account a number of current and emerging trends and prospective factors which are expected to be influential during the 1990's and into the early twenty-first century.

Priority and specific program areas at NRC are determined through discussion, consultation and assessment activities as part of the strategic planning process. NRC resources are allocated primarily based on historical allocations. Allocation decisions are made by the President jointly with the three Vice-Presidents.

3.3 Project Selection

The peer review process is used to select projects at NRC. Methodologies for research selection vary from each of the 16 institutes. However, the criteria used in peer review can be generally classified into the following:

i) Attractiveness
- Potential benefits: economic development, national welfare, national security or the advancement of knowledge;
- Ability to capture benefits: potential for exploitation of research efforts and to convert them into commercial or other types of returns including the capacity of industry to absorb the new technologies;

ii) Feasibility
- R&D potential: technical feasibility of the project including technical risk assessment considerations;
- R&D capacity: available human, financial, physical and other resources to carry through the project;

iii) Partnership
- Involvement of an industrial or external partner in the project.

3.4 Project Monitoring

The head of the institute undertakes a formal program/project review bi-annually to determine scientific accomplishments and problems encountered. The basis of the review is the Operational Plan prepared at the start of the year which defines the milestones, deliverables and performance expectations of each project.

Monitoring is also be undertaken on an individual basis through the Performance Planning and Review Process. Each researcher sets out his/her individual milestones, deliverables and performance expectations for each project that he/she is involved with. This report includes a daily time reporting for each project.

Monitoring the resource expenditures of each project utilizes a computerized accounting facility which integrates purchases and other expenditures and the daily time reporting of personnel.

4. Canada Centre for Mineral and Energy Technology

4.1 Corporate Plan

The Canada Centre for Mineral and Energy Technology's (CANMET) primary strategic and operational document is called the CANMET Business Plan. The plan is supportive of the government's economic policy of attaining "prosperity through competitiveness." One building block of this policy is science and technology. The plan translates this policy into strategies and programs directed at promoting improved technological performance and enhancing the competitiveness of the Canadian minerals, metals and energy industries.

The plan shows a schematic relationship of its R&D programs by categorizing them into four types with corresponding targets, namely: strategic (45%), incremental (35%), mandated (10%) and exploratory (10%). This reflects not only an attempt at a balanced program mix, but defines CANMET's special niche in the research market as between universities which focus on exploratory research, and the private sector which focuses on short- to medium-term projects.

Client-orientation is a prevailing theme in the plan. Programs are focused on client needs and relevance is ensured through emphasis on cost sharing and cost recovery. Increasing the competitiveness of clients is the established objective of all activities classified under productivity work.

The plan provides for the conduct of a biennial client survey to look at the level, quality, appropriateness and relevancy of CANMET-client business relationships.

The plan outlines a corporate marketing strategy which manifests the importance given to clients and partners both in the public and private sectors, and in the provincial, federal and international levels. The marketing strategy features face-to-face marketing, market-oriented analysis of CANMET's R&D products and services and promotional activities on the organization, its facilities and expertise.

Furthermore, the plan includes key performance indicators developed to measure CANMET's effectiveness in working with industry clients. These include cost recovery revenue, client share of task-shared work and client share of cost-shared work. This also amplifies the business-like approach that CANMET has adopted. The plan, however, also indicates that while revenue generation is given premium, CANMET is dedicated to building its scientific base.

4.2 Technology Planning

The Minister's National Advisory Council to CANMET (MNACC) which is an industry-led advisory board, and its six technical advisory committees review the technical programs annually. They make recommendations to the Minister on Energy, Mines and Resources on the future direction of these programs and on the broad level of resources that should be allocated. Concerned units of CANMET respond to these recommendations and discussions are conducted.

The Panel on Energy Research and Development (PERD) and the new Deputy Minister's Advisory Committee on CANMET (DMACC) are two other bodies which influence policy direction and advice on its plans and programs. The PERD coordinates distribution of funds from the Program on Energy R&D to 12 federal departments and agencies. CANMET manages 55 percent of total PERD funds.

The DMACC ensures appropriate linkages between the policy of the Department of Energy, Mines and Resources, the corporate sector and CANMET.

CANMET's R&D thrusts are on four areas: environment, health and safety, energy, and minerals and metals. The identification of specific activities result from the interplay of many factors, such as: advice from MNACC, technical advisory committees, PERD and other policy groups; the government's Green Plan and prosperity initiatives; the development of Business Opportunity Documents to assess marketability of new technologies and commercial application of new products and services; and daily interaction with clients and partners.

Resource allocation is largely determined by historical spending and allocation, e.g. for energy, new government programs and initiatives e.g. environment, and other incremental adjustments based on the requirements submitted by each laboratory.

4.3 Project Selection

Most projects are client-based and the primary criteria for project selection is client commitment. Highest priority is given to projects with actual support from client in terms of people or funding.

In addition, the following factors are also considered: demonstrated industrial need; potential for significant return; transfer of technology likely in three to five years; relative contribution level dependent on risk, interest to others in industry, and disposition of intellectual property; consistency with CANMET mandate; and availability of expertise.

For the core or in-house projects, long term potential and scientific merit are the main criteria for selection.

4.4 Project Monitoring

Monthly to quarterly, Directors assess the state of their projects. Semi-annually, the Assistant Deputy Minister meets with each Director General, Director and key staff to review relevant pre-established performance indicators and strategic thrusts.

Project monitoring is aided by the Management Information System (MIS) to respond more effectively to the needs and requirements of users. The software system used is Ingres for access speed and flexibility. The MIS is anchored in the central office but is linked to all CANMET laboratories across the country.

The MIS contains information on the technical, financial and personnel aspects of each type of project. On a monthly basis, all milestones due are printed out and distributed to project leaders concerned. At the end of the month, project leaders report whether the planned completion date has been attained, whether there is a new actual completion date or whether the completion date has to be revised. In cases where there is a revised completion date, subsequent milestones and completion dates are revised. Comments are given regarding the attainment of the milestone. A project accomplishment status to date is indicated by a percentage completion beside the milestone last accomplished.

Purchases and other expenditures as well as time reports of research personnel are integrated into the MIS.

Storage and retrieval of information in the MIS are limited only to concerned personnel identified by their access code.

Information is retrieved in pre-established formats for each component of the MIS.

5. **Energy, Mines and Resources**

5.1 Program Evaluation

Program evaluation is conducted by the Evaluation and Audit Branch of the department of Energy, Mines and Resources (EMR) as required under the Treasury Board circular which states that as a general policy "Departments and agencies of the federal government will periodically review their programs to evaluate their effectiveness in meeting their objectives and the efficiency with which they are being administered."

Program evaluation is defined as the periodic, independent and objective review and assessment of a program to determine, in the light of present circumstances, the adequacy of its objectives, its design and its results both intended and unintended. Matters such as the rationale for the program, its impact on the public and its cost effectiveness as compared with alternative means of program delivery are reviewed in this context.

A 'program' is a major activity or group of activities designed to achieve specific long-term objectives of an organization. Program is sometimes synonymous to large scale project or the whole institution.

Program evaluation is considered an integral part of the management review and monitoring function and provides input into planning and budgeting. Planning and budgeting involves setting goals and objectives, developing general strategies and operational plans. Implementation involves carrying out these plans. Reviewing and monitoring involves the determining of the performance and results of the operations against expectations, objectives and plans.

Program evaluation as a review and monitoring function, providing the client with independent, objective information and evidence on the results of a program. This information provides feedback which can be used both to improve current operations and to provide a basis for future strategic planning. Program evaluation completes the package of formal review and monitoring mechanisms which are essential for good management today. See illustration, Fig. 6.

5.2 Features of the Policy on Evaluation

The program evaluation function in EMR as in each department is the responsibility of the deputy head. He is the client of the evaluation in that he selects the order of programs to be evaluated, ensures that findings are communicated to relevant levels of management and that appropriate recommendations are implemented.

All programs should be evaluated on a periodic basis of 3-5 year cycle or longer as may be required. Program evaluation studies should be designed and carried out in an objective manner. Therefore, the program evaluation function should be independent of line management.

At the EMR, preliminary evaluation of a program is conducted by the Evaluation and Audit Branch and detailed evaluation is contracted out to an independent consulting group.

5.3 Basic Program Evaluation Issues

Program evaluation is considered to cover four classes of issues. There are questions under each issue which serve as a guide in the evaluation of a program. These issues and possible questions are the following:

Issue	Question
Program Rationale (Does the program make sense?)	- To what extent are the objectives and mandate of the program still relevant? - Are the activities and outputs of the program consistent with its mandate and plausibly linked to the attainment of the objectives and the intended impacts and effects?
Impacts and Effects (What has happened as result of the program?)	- What impacts and effects, both intended and unintended, resulted from carrying out the program? - In what manner and to what extent does the program complement, duplicate, overlap or work at cross-purposes with other programs?
Objectives Achievement (Has the program achieved what was expected?)	- In what manner and to what extent were appropriate program objectives achieved as a result of the program?
Alternatives (Are there better ways of achieving the results?)	- Are there more cost-effective alternative programs which might achieve the objectives and intended impacts and effects? - Are there more cost-effective ways of delivering the existing program?

5.4 Evaluation Methodology Overview

Based on a review of the state of the art and the experience in the evaluation of government R&D programs, EMR has summarized various evaluation methodologies for the various stages of R&D are briefly described below and summarized in Table 2.

i) Peer Reviews

Peer evaluation is an analysis and evaluation of a program by persons of equal standing or rank in the scientific community, skilled in the disciplines which are under evaluation. This type of evaluation is normally concerned with an evaluation of the quality rather than the effectiveness of the work.

ii) Value Analysis

This technique is a variant of the peer review, in its attempt at quantitativeness. The procedure is to develop a list of criteria, each criterion having a different set of weights to compensate for differences in the relative importance of the criteria. Each criterion could have levels with different assigned numerical weights.

iii) Client Surveys

This is an especially relevant and useful technique for the evaluation of government R&D, with its multiplicity of objectives, and a broad spectrum of clients.

The objectives of the survey and the questions to be posed should be well planned, as this can be an expensive technique. Data collection may done through mail out/mail back, interviews, telephone surveys or a combination of these methods.

iv) Cost-Benefit Analysis

Attempts at cost-benefit analysis have been made since the advent of discounted cash flow techniques. Its use in R&D is limited if the payoff is in the distant future and hence returns will be heavily discounted and count very little, as compared to expenditures in the recent past. It is not useful if the value assigned to various possible outcomes are largely arbitrary and the numerical results obtained are thus of dubious value.

The field of agricultural research has certain characteristics that allow the calculation of economic returns from investment in research. The investment is largely from public funds, the work is carried out in a few identifiable laboratories, aimed at very specific objectives and with a single identifiable client. Furthermore, data on productivity, resource inputs to agriculture, and on research expenditure are regularly reported in government publications. For example, economic return from research on hybrid corn is estimated to exceed 50 percent.

v) Indicators

Indicators are chosen to measure the output and impact of scientific research and development. An indicator is a measure selected for elucidating a particular concept, where a measure is a numerical description of some empirical aspect of a phenomenon. A concept is an idea or notion of some intangible social phenomenon such as inventiveness, poverty or intelligence.

For an indicator to be useful, it must be valid, that is, it must fit the concept according to an explicit model or theory. For example, if the number of patents is chosen to measure the output of applied research, it implies that, if the resources for applied research are increased, then the number of patents will increase. Often, a single indicator may not be sufficient. A multiple of indicators may be necessary to measure the total output.

One indicator is patents which serve as a measure of the output of scientific activities. Another indicator is citations which is directly related to the number of times a journal article is cited. Hence, citation indexes are also a measure of the quality of R&D output.

vi) Productivity

Productivity measures are derived from a comparison of the output with the input, in order to formulate a ratio. Measurement of output in research is a difficult process since the obvious countable "outputs" of research such as publication and prototype devices are so different from one another in their content and probable impact that they should be used with caution. Further, efficiency is generally not a major consideration in scientific work.

vii) Probabilistic Methods

These methods become especially useful and practicable where efforts are concentrated on projects dealing with specific new products or processes. In general, these methods are used not only to evaluate the value of completed developments, but also as aids in the resource allocation process and in the on-going management of research projects.

The methods vary in complexity, but the procedure consists of assigning weights to a series of critical factors by several key person in an organization. If the total weight is below a certain value, the project may be abandoned.

viii) Organizational Characteristics

It has been recognized that not only must the inputs and outputs of R&D must be measured, but also the effectiveness of research units. However, the lack of standards against which the organizational health of research units can be compared presents difficulty in the use of this method. Valid instruments in the form of questionnaire surveys are required. However, conclusions from statistical analysis must be tempered with human judgment, which requires analysts skilled in the art.

5.5 Program Evaluation: The Case of CANMET

The Canada Centre for Mineral and Energy Technology (CANMET) under EMR was evaluated in 1991 and the following 10 issues were addressed:

i) What is the role of CANMET is the provision of "public good" oriented work?
ii) Are current research and development thrusts complementary to provincial mineral and energy initiatives?
iii) How effective is CANMET in responding to the research and development requirements and needs of the mineral and energy industry sector?
iv) How successful has the science and technology results of CANMET been transferred to end-users?
v) What is the responsibility of CANMET for maintaining unique national facilities for testing and analysis?
vi) Is CANMET contracting-out in an effective manner?
vii) What have been the effects of resource reductions on CANMET?
viii) How successful is CANMET in responding to federal policies?
ix) What lessons can be learned by comparing CANMET with other laboratories that perform science and technology?
x) What is the role of CANMET in contributing to the mix of research and development performed in Canada?

The approach to this evaluation entailed two phases. Phase 1 focused on internal data collection including visits to the laboratories, interviews with laboratory managers, preparation of profiles of selected projects, and review of various types of reports and documents. Phase 2 involved external data collection from officials of CANMET's advisory council and other concerned agencies, clients or intended beneficiaries of the selected R&D projects, industry associations, and interviews with laboratories in other jurisdictions.

The data includes factual information as well as perceptions and viewpoints of CANMET officials and external groups. Thus, the findings are presented to indicate clearly where the data is in the form of viewpoints rather than facts.

In 1990, CANMET's recently completed R&D projects were reviewed and nine were selected for more detailed probing of their costs and benefits. For each project, the number of person-years, person-year costs of the project and the costs of contracted services are computed. The social discount rate is then used to adjust the costs to a common base for comparison.

The number of years of CANMET activities that could be supported by the social benefits of the selected projects is then assessed. This is done by deducting the costs from the estimate of the benefits . The method then calculates the number of years of CANMET costs that are represented by the benefits of the selected projects.

Benefits are defined as the gains in production or consumption possibilities for society minus the private sector costs in obtaining goods and services affected by the CANMET activities. Benefits are measured in measured in terms of an increase in producer surplus (difference between the selling price and the opportunity cost of production) and an increase in consumer surplus (difference between the maximum willingness to pay and the price the consumer has to pay) for the affected goods and services.

V CONCLUSIONS AND RECOMMENDATIONS FOR IMPROVEMENT OF DOST TECHNOLOGY PLANNING AND PROJECT MANAGEMENT

1. Planning Directions

1.1 Conclusions:

1.1.1 Global competitiveness and how Canadian industries can be made more competitive in the global market is the overriding goal of all R&D efforts. The R&D institutions are strongly supportive of the goal of economic and social prosperity by securing Canada's competitive position in the global market.

1.1.2 Client service is the immediate objective of R&D endeavors. The client or the user of R&D outputs is placed at the center of R&D investments. Client need is the determining factor in the conduct of R&D work as a basis of relevance.

1.1.3 Business-like is the manner of operations that R&D institutions strive for. Emphasis is placed on the generation of revenues from R&D and related activities as well as leveraging from other external sources especially the private sector. Specific revenue and leverage targets common in business enterprises are being set in R&D institutions. Since operation is business-like and market-driven, marketing is a line function in R&D institutions.

1.1.4 Parallel to client orientation and revenue generation is the value given to scientific excellence. Importance is given to world class research/leading edge roles/exploratory R&D to build the scientific base. Resources are allotted for such non-client-based endeavors as basic research or long-term strategic research.

1.1.5 The concern for a balanced program mix is reflected in the allocation of either resources or types of activities. Percentage distributions are set for various types of activities e.g. exploratory versus strategic R&D, or in budget allocations e.g. client-based versus internal R&D.

1.1.6 A selective technology approach is evident in that the focus of R&D is on a number of technology areas. These are strategic technologies or technologies vital for global competition.

1.1.7 Collaboration is the common mode of operation. Networks, consortia and partnerships is being expanded at the national and international levels. Proactive efforts are being made to link with other countries especially in the Asia Pacific Rim.

Recommendation No. 1

A client/demand-oriented approach to S&T development

The present Philippine S&T Master Plan is supply-oriented in that its strategies are primarily directed at providing the technologies to attain industrialization. To complement this, the demand side of S&T must be stimulated. Client needs as the basis of technology development for industrialization must be a pervading theme in strategy and program formulation.

A client/demand-oriented approach is largely operationalized in technology planning, project selection and marketing functions. The number of projects with full or partial funding from client must be increased to help ensure relevance. For other strategic projects, an immediate user should be identified whose awareness and interest must be generated. Marketing must be established to actively promote programs/projects and expertise.

The client or industry orientation advocated here is one tempered with the social objective and the public good mandate of government. R&D institutions must, to a larger extent, deliver technologies to benefit the overall industry and not individual clients. This can be done by focusing on generic technologies or general processes which can be applied industry-wide; or technologies of general interest to the industry and could be made available to the overall industry without affecting free market competition.

An individual company may be considered if it is dominant in the industry and its success reflects the health of the industry. Few companies may also be served if they dominate the industry and assisting them with their unique productivity problems would collectively strengthen the industry.

Recommendation No. 2

A balanced program mix

R&D institutes in the Philippines cannot yet go into intensive revenue generation since R&D in the private sector is minimal. Unlike Canada where industry expenditures is 56 percent of total national R&D expenditures, private sector R&D expenditures in the Philippines represents only about 20 percent of total. The majority of the firms are small and medium with no R&D budget while large firms are subsidiaries of multinational corporations.

On the other hand, there must be emphasis on client-based R&D as described above. The primary purpose is to ensure relevance more than generate revenues. In addition, there is also the need to develop capabilities in certain areas to sustain the flow of technology inputs to client groups. There is, therefore, a need to establish some agreed levels for the different types of S&T work. The following may be considered by DOST as the lead science agency:

	Present (% of budget)	Next 5 Years (% of budget)
Exploratory	5	10
Contract/Client Based	5	25
Strategic/Non Client Based	70	50
S&T Services	15	15

Exploratory or basic research has been greatly reduced in recent years to about five percent of expenditures with the emphasis on priority areas. The prevailing norm in Canadian institutions is 10 percent. The present level of five percent may be increased to 10 in view of the greater need to serve industry while not neglecting the building up of future technological capabilities.

Contract R&D or work undertaken for specific clients and partners must be emphasized to increase relevance. The increasing shift to demand-oriented client-based R&D must increase from a present estimated level of five percent to 25 percent in the next five years.

Non-client based but nevertheless strategic projects should be reduced to 50 percent from a present high of 70 percent. This level should be sufficient to address the public good mandate of R&D and to sustain innovation at the present period when private industry R&D investment is not substantial. However, awareness and acceptance of the project by intended users must be developed.

S&T services including testing, analysis, government certification etc. may be maintained at the same level since most of these are available only in government laboratories.

Recommendation No. 3

Establish milestones of technology development

To make the vision concrete, specific technologies or technology stages must be outlined and contrasted with the present state. These will serve as measures by which progress in implementation of the plan can be assessed and efforts towards agreed outputs more closely guided. Below is an example for the forestry sector taken from ARC's corporate plan:

Year 1990	Year 2000
Structural components	Engineered wood composites
Innovative products	Biocomposites
Glues and resins	Advanced polymer systems

Milestones for each leading edge area can be developed from the Action Plan for each leading edge prepared by the Technical Panels. Program listing should be reviewed and refined to arrive at concrete benchmarks.

Recommendation No. 4

Translation of objectives to performance indicators

The S&T Master Plan should provide a mechanism for evaluation by ensuring that the performers of S&T are assessed in terms of measures consistent with the plan objectives. Performance indicators should be aligned with established targets e.g. client-oriented R&D, resource commitment.

2. Technology Planning

2.1 Conclusions:

2.2.1 R&D institutions in Canada engage in strategic planning in that they develop and document the future role of their organization, its corporate goals, values, policies and objectives. The time frame varies, but the strategic plan provides the directions for such long term decisions as technology outputs in year 2000 to such proximate decisions as the next project.

2.2.2 Technology planning is undertaken primarily through the process of consultation. There are two main streams: internal, and external to the organization. External discussions and consultations are conducted with a broad range of clients, industry, S&T performers and other stakeholders. Internal reviews and consultations are also conducted with advisory/policy committees/boards/governing councils as well as management and staff of the institution.

2.2.3 Environmental scanning is undertaken formally and informally in that current issues, events and emerging trends in the external social-economic-political-technological environment are taken into account.

2.2.4 Formal assessment and evaluation also provide a foundation for a strategic plan.

2.2.5 Allocation of resources is primarily based on historical spending and allocation.

Recommendation No. 5

A technology-based framework for strategic choices and resource allocation

Except for the benefit-partner's commitment grid of ARC, no technique has been offered from Canadian institutions. There was an expressed need for a framework for strategic choices, intentions to conduct technology needs surveys and technology status assessments of industry, and institutionalization of environmental scanning.

While consultation is the most practical approach, there is a need for a framework for strategic choices. Rather than an inventory of all equally important technology areas, there should be a documentation of conscious choices and indications of priority ranking. This is most important in view of very limited resources.

The Technology Atlas prepared by UN-ESCAP offers a technology-based planning framework. Initial efforts at DOST to apply the methodologies should be pursued just as in Indonesia, Thailand and Malaysia. The methodologies included in the Technology Atlas are: technology needs assessment, technology status assessment, technology capability assessment, technology climate assessment. These methodologies call for identifying the sources of technologies and priority ranking which can then serve as basis for allocation.

These methodologies can serve as the framework for strategic choices by facilitating the identification of technology outputs, the technologies required and relative importance based on certain defined parameters. This methodology still employs consultation with experts and stakeholders but guides the thinking process and conscious choices.

Recommendation No. 6

Strengthening of DOST internal consultation in the updating of the S&T Master Plan

While external consultation has been extensive in the formulation of the first S&T Master Plan, internal consultation within DOST as the lead implementing agency must be institutionalized. In the past, DOST scientists and engineers participated only when invited as members of STCC technical panels. Internal consultation must be formalized to allow wider participation by the core of scientists and engineers in the decision-making process. Their position can then be fused with inputs from external consultations.

3. **Project Selection**

3.1 Conclusions:

3.3.1 Modes and criteria for project selection in Canadian R&D institutions revolve around the client. Project selection ranges from being purely client-based, that is, dependent on specific client needs; to a committee decision using a set of criteria.

3.3.2 In committee criteria, the major factor is client's funding commitment, it being an indicator of the relevance of the project and recognition of the institution's capability. Quantitative project selection is not commonly used. No specific weights are assigned to each criteria by which the project is scored and ranked. The prevailing mechanism of project selection is committee discussion and consensus among member peers and stakeholders.

Recommendation No. 7

A generic client-centered criteria for project selection

Project selection criteria are crucial to research management practice as determining factors of the nature of research activities that will follow. Project selection criteria is a tool for influencing R&D and should be consistent with established goals, values and priorities.

While committee review is the most common mode of project selection, the decision parameters should be established. The list of criteria should be well-defined and assigned numerical weights to reflect the relative agreed importance of each. This is important especially during a period of redirection and reorientation of programs. Thus, there is a need for consistent and effective criteria for project selection.

The importance of a client-oriented approach to technology development and a program mix have been discussed and proposed above. These and other relevant factors should be incorporated in project selection at DOST. The next page shows a proposed selection criteria for projects in the leading edges.

Each criterion has levels of responses with corresponding weights. The maximum possible score is 91. Scores may be made by the coordinating unit as part of the preliminary work and by the technical committee. Score sheets should be accompanied by explanatory notes.

4. Project Monitoring

4.1 Conclusions:

4.4.1 Project monitoring is undertaken by the management of Canadian R&D institutions through a review of the progress reports submitted either quarterly or bi-annually. Contract and joint projects are monitored according to terms stipulated in the contract or agreement.

4.4.2 Automated information systems covering the financial and the technical aspects of projects are a vital tool of project monitoring. The financial part of the information system is generally the first to be established because of the importance of cost in work for clients.

4.4.3 The CANMET Sector Management Information System (SMIS) would be an excellent model for DOST. It is designed to meet the needs of management, project leaders and administrative staff by providing a comprehensive, integrated system for planning and controlling operations. Its modules include financial, project prospectus, personnel time reports, contract information and cost recovery.

4.4.4 The following are salient features of CANMET's and similar project information systems which should be incorporated as improvements to the DOST pilot R&D Management Information System (MIS):

- The MIS should integrate accounting, personnel and project technical information;
- Financial accounting should also be project-based as a detailed breakdown of the fund-based accounting;
- The work breakdown structure should be reflected in the project profile and regularly updated based on reports of actual performance as the project proceeds;
- Project objectives and milestones corresponding to individual work activity must be clear and explicit;

- The MIS should allow the tracking of project progress by monitoring the completion of milestones. Deviations from the plan must be explained to rationalize revisions;
- Per cent completion must be calculated by adding the earned value of completed milestones. Only completed milestones are given percentage value. By comparing actual versus target progress, early warning of deviations are obtained and appropriate action taken.

Recommendation No. 8

An integrated financial-personnel-project R&D Management Information System

A proposed framework for the DOST R&D MIS is shown on the next page. The system draws inputs from the Department Financial System anchored at the Financial and Management Service (FMS). All agencies input data on allotment schedule, fund-based financial expenditures, project-based financial expenditures and cash receipts to this system.

Likewise, the system draws data on project time from the Department Personnel System anchored at the Administrative and Legal Service (ALS). All agencies input directly to the R&D MIS data on project profiles, work plan and quarterly technical reports. The R&D MIS is anchored at PES but linked to all agencies.

5. **Program Evaluation**

5.1 Conclusion:

5.5.1 The conduct of regular evaluation of government programs in Canada has provided important information for decision-making and increasing accountability. The evaluation of R&D projects and institutions has been demonstrated as not an impossible task but an undertaking which can add meaning and significance to an otherwise diffused and unquantifiable undertaking.

Recommendation No. 9

Institutionalization of the program evaluation at DOST

The evaluation of programs in the S&T Master Plan should be initiated. The exercise may be guided by principles and methodologies used by EMR. Evaluation can start with more visible programs with intended national impact in the area of technology transfer and commercialization. Examples would be the National Trichoderma(Organic Fertilizer) Project and the Small-scale Soapmaking Technology.

Figure 1

STCC ORGANIZATION CHART

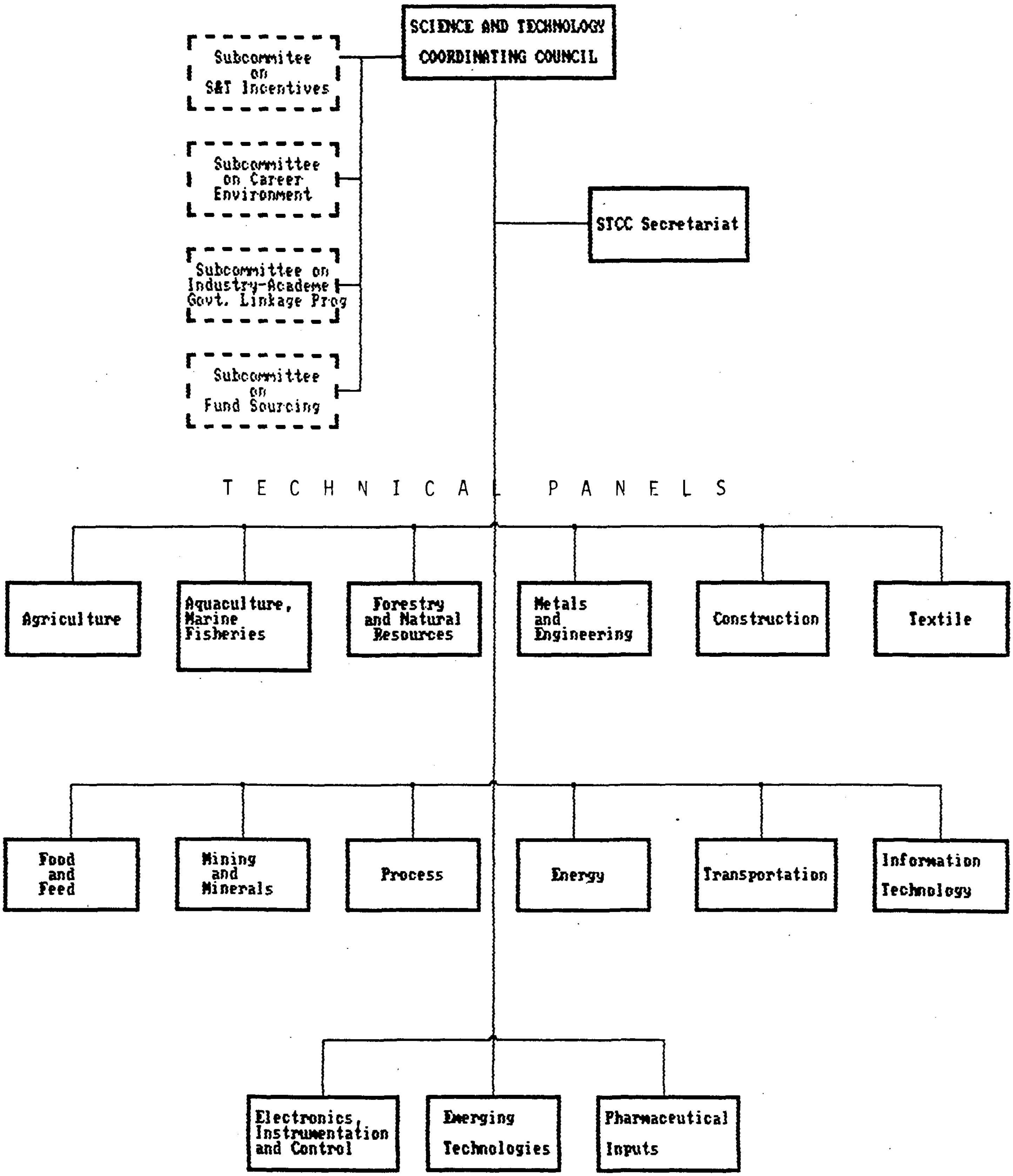
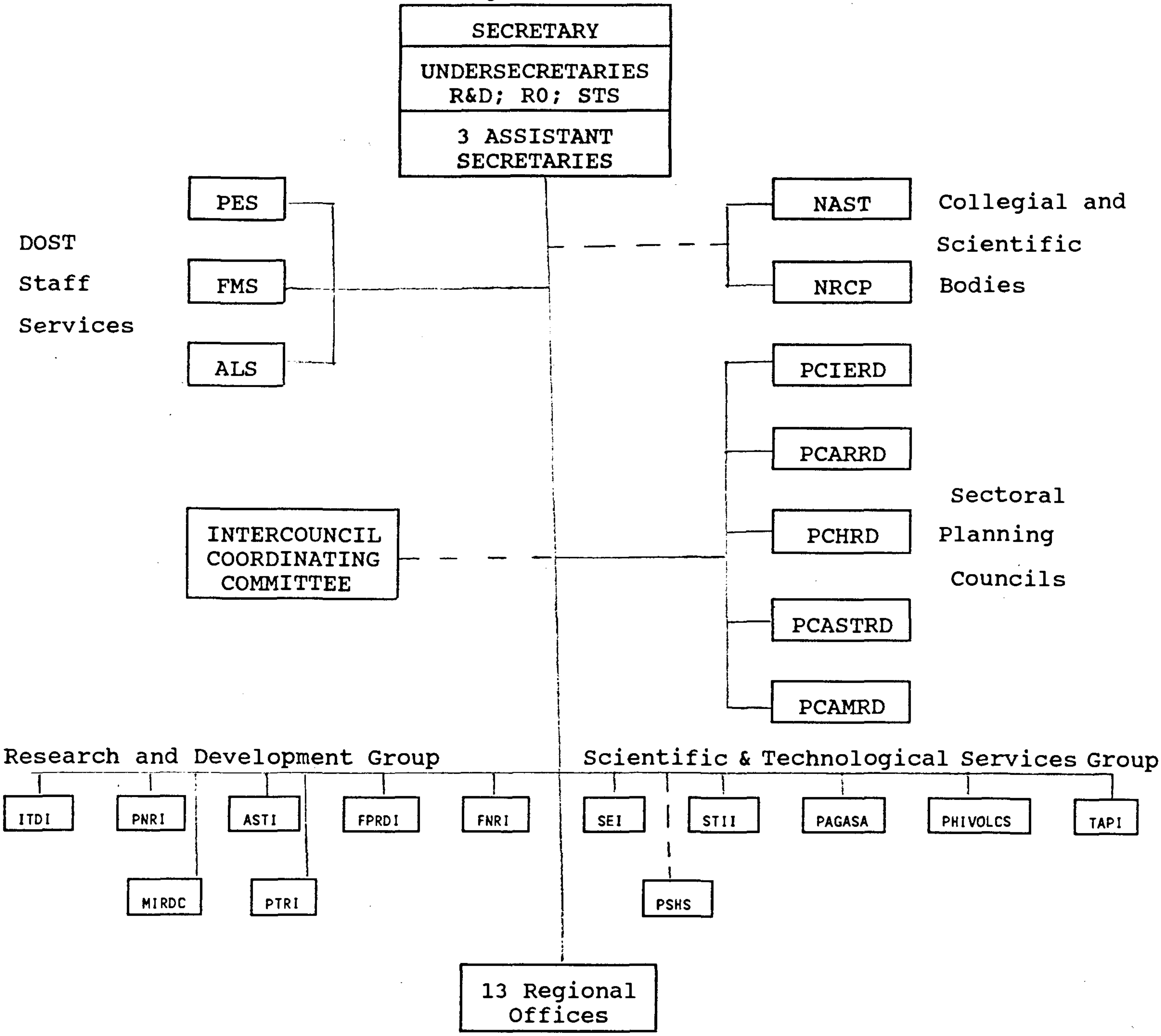


Figure 2
DEPARTMENT OF SCIENCE AND TECHNOLOGY

Organization Chart



LEGEND:
Supervision and Control
Attached-for Policy Formulation

STAFF SERVICES

PES - Planning and Evaluation Service
FMS - Financial and Management Service
ALS - Administrative and Legal Service

COLLEGIAL AND SCIENTIFIC BODIES

PCIERD - Philippine Council for Industry and Energy Research and Development
PCARRD - Philippine Council for Agriculture, Forestry, Natural Resources Research and Development
PCHRD - Philippine Council for Health Research and Development
PCASTRD - Philippine Council for Advanced Science and Technology Research and Development
PCAMRD - Philippine Aquatic and Marine Research and Development

RESEARCH AND DEVELOPMENT GROUP

ITDI - Industrial Technology Development Institute
PNRI - Philippine Nuclear Research Institute
ASTI - Advanced Science and Technology Institute
FRDI - Forest Products Research and Development Institute
FNRI - Food and Nutrition Research Institute
MIRDC - Metals Industry Research and Development Centre
PTRI - Philippine Textile Research Institute

SCIENTIFIC AND TECHNOLOGICAL SERVICES GROUP

SEI - Science Education Institute
STII - Science and Technology Information Institute
PAGASA - Philippine Atmospheric, Geophysical, Astronomical Services Administration
PHIVOLCS - Philippine Institute of Volcanology and Seismology
TAPI - Technology Application and Promotion Institute
PSHS - Philippine Science High School

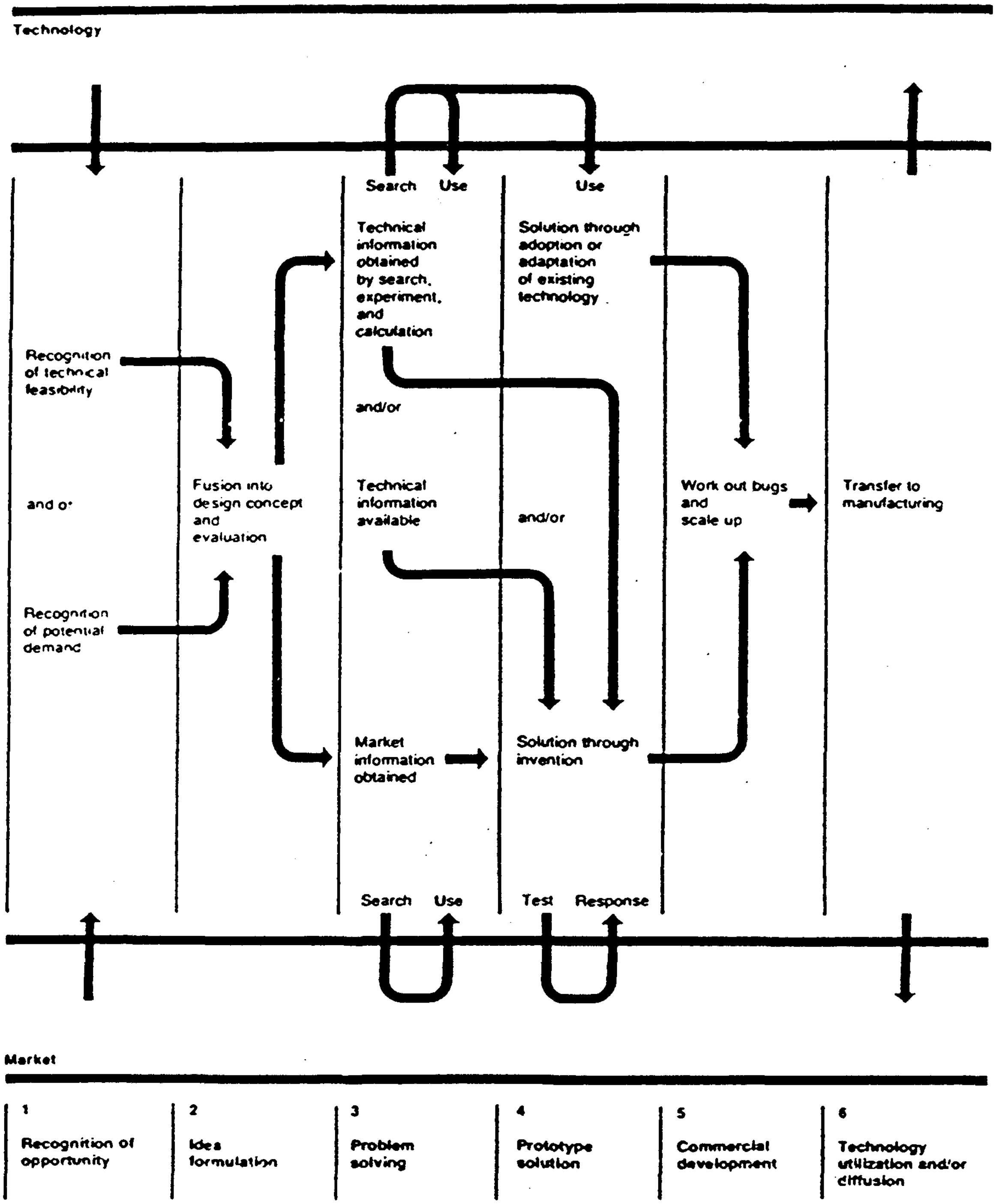


Figure 3 —*The process of technological innovation*

(Reprinted with permission from E. B. Roberts and A. L. Frohman, "Strategies for Improving Research Utilization," Technology Review, vol. 80, no. 5, March/April 1978.)

Figure 4

PROJECT LIFE CYCLE AND CRITICAL SUCCESS FACTORS

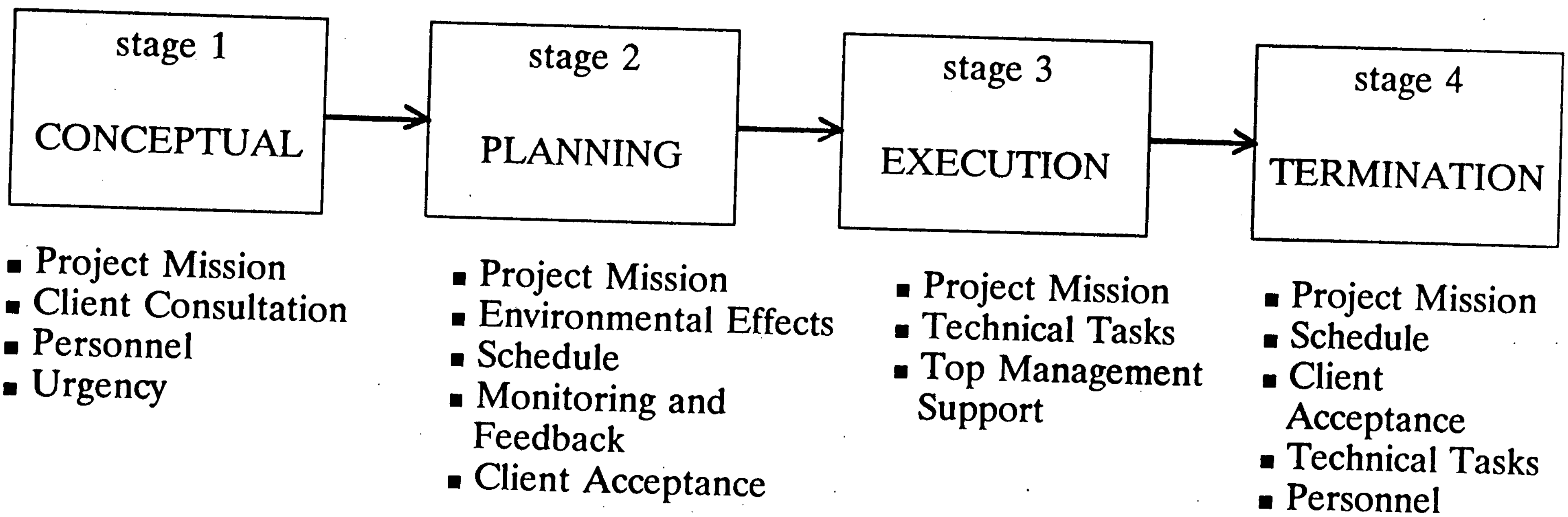


Figure 5

ARC BENEFIT - PARTNERSHIP GRID

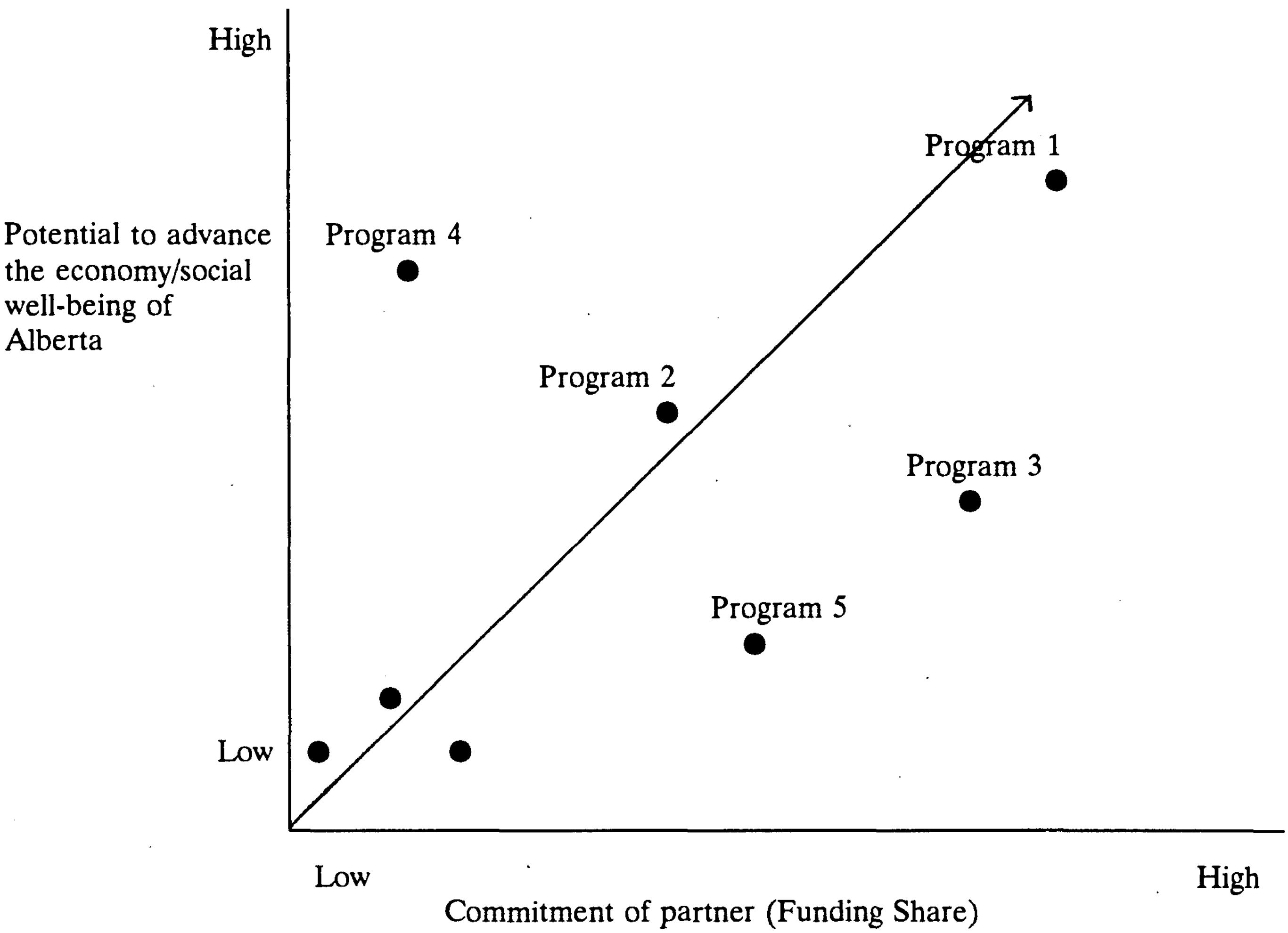
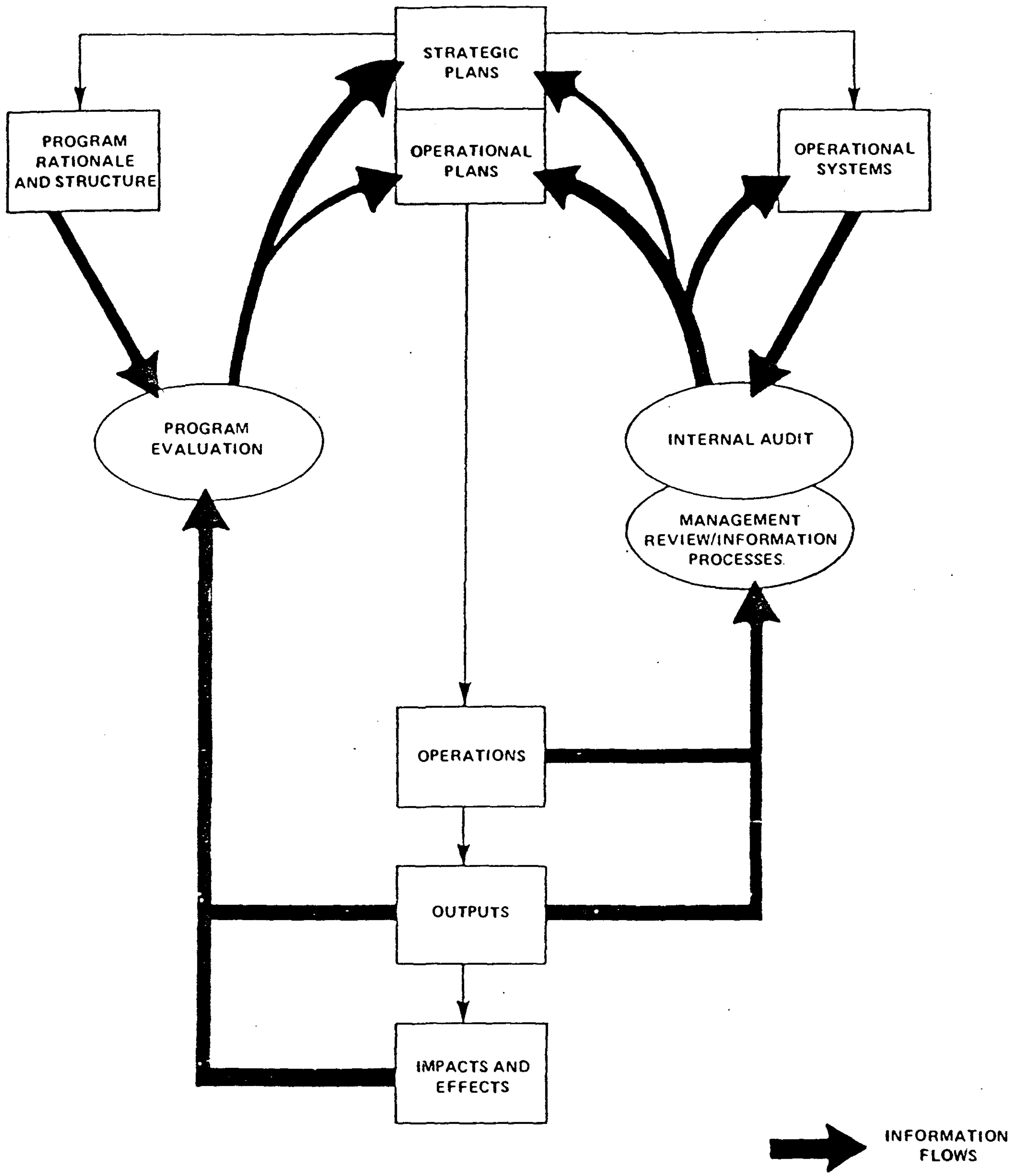


Figure 6

MANAGEMENT REVIEW AND MONITORING FUNCTIONS



Source: Guide on the Program Evaluation Function
Treasury Board of Canada
Comptroller General
May 1981

Tabl

Summary of MOT Approaches

Institute	Management Of Technology (MOT) Area				
	Corporate Plan	Technology Planning	Project Selection	Project Monitoring	Project/Program Evaluation
1. Alberta Research Council (ARC)	A Vision of Year 2000 (1991-2000)	Strategic	Technical Committee / Criteria-based	Manager; Agreement-dependent	-
2. Saskatchewan Research Council (SRC)	Implicit in Various Documents	Strategic-Diagnostic	Client Need-dependent	Contract-dependent / Automated Financial Information System	-
3. National Research Council (NRC)	The Competitive Edge (1990-1995)	Strategic	Peer Review Committee / Criteria-based	Institute Head; Computerized Accounting Facility	-
4. Canada Centre for Minerals and Energy Technology (CANMET)	CANMET Business Plan (1992-1995)	Strategic-Operational	Client Commitment-dependent	Director; Comprehensive / Automated MIS	-
5. Treasury Board/Energy, Mines and Resources (EMR)	-	-	-	-	Client Survey Cost-benefit analysis Internal data collection
6. Department of Science and Technology (Philippines)	S&T Master Plan	Strategic-Indicative	Experts Committee / Criteria-based Technology-centered	Undersecretary; Written Reports / Pilot MIS	National S&T Indicators

Table 2 - OVERVIEW OF EVALUATION METHODOLOGIES

	Stage / Evaluation Method	I Basic Research	II Basic Research Output	III Applied Research	IV Outputs of Applied Research	V Develop-ment & Testing	VI Outputs of Development & Testing	VII Impact on Clients
1.	Peer Review - Value Analysis	***	***	**	**	*		
2.	Client Survey	*			**		***	
3.	Cost-Benefit Analysis				*		**	***
4.	Indicators							
	- Patents	*			**		***	
	- Publications	***			*		*	
	- Citations	***			*			
5.	Productivity			*		***		
6.	Probabilistic Methods			*		***		
7.	Organizational Characteristics	***		***		**		

NOTE: The larger the number of asterisks, the more relevant and applicable, and hence more important is the evaluation method.

Source: The Evaluation of Government Research and Development Programs
Central Evaluation Group
Energy, Mines and Resource Canada
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9. Pinto, J. and D. Slevin, "Critical Success Factors in R&D Projects," in Research Technology Management, January-February, 1989, p.32

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2.3 Partnership Report (A report on the "Partnership in Education" program - a cooperative effort of Saskatoon Catholic Schools and the Saskatchewan Research Council) Vol. 3 No. 1 April 1992

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4.3 Introduction to the CANMET Sector Management Information System (SMIS)

4.4 Project Management as Practised at Batelle (CANMET Memorandum) from D.B. Stewart, September 24, 1991

4.5 Project Selection Methodology and Parameters, Mineral Program Office, CANMET, June 1988

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4.7 Review of Selected CANMET Research and Development Projects

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5.2 Guide on the Program Evaluation Function, Treasury Board of Canada, May 1981

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5.4 Program Evaluation Study: Canada Centre for Mineral and Energy Technology, July 1991

6.0 Industry, Science and Technology Canada:

6.1 Innovaction The Canadian Strategy for Science and Technology

7.0 Department of Science and Technology:

7.1 Science and Technology Master Plan, July 1990

7.2 STCC Brochure

PROPOSAL PRIORITIZATION PROCESS

TITLE ______________________
____

SCORES

***PARTNER/CLIENT RESOURCE COMMITMENT**		____	____
% of Project Cost:			
>90%	= 20		
50-90%	= 15		
Less 50%	= 10		
None	= 0		
***PURPOSE OF R&D**		____	____
Client based	= 10		
(With full or partial contribution from client/partner)			
Strategic	= 8		
(No client, but within leading edges)			
Exploratory	= 4		
***SCIENTIFIC/TECHNICAL MERIT** (Additive, Max 13)		____	____
Feasibility	= 5		
Innovativeness	= 4		
Outstanding Scientific Contribution	= 4		
***OPERATIONAL RISK** (Re infrastructure, expertise, management)		____	____
Low risk	= 8		
Med risk	= 4		
High risk	= 2		
***POTENTIAL BENEFITS** (Social, economic, etc.)		____	____
High	= 10		
Medium	= 8		
Low	= 4		
***MAGNITUDE OF IMPACT**		____	____
National	= 10		
Regional	= 8		
Local	= 4		
***UTILIZATION POTENTIAL** (Time frame of technology transfer)		____	____
Immediate	= 10		
3-5 years	= 8		
More than 5 years	= 4		
COMPLEMENTARITY WITH OTHER LEADING EDGE PROJECTS	= 5	____	____
MANAGEMENT DISCRETION	= 5	____	____
MAX POSSIBLE	= 91		

TOTAL ____ ____

DATE ____ ____

SIGNATURE OF
HEAD EVALUATOR